Indian Journal of Anatomy
Volume 5 Number 1, January - April 2016
DOI: http://dx.doi.org/10.21088/ija.2320.0022.5116.6

Transabdominal Sonographic Quantitative Analysis of the Fetal Cardiac Length in Third Trimester of Gestation

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Abstract

Antenatal ultrasonography is noninvasive and done on routine basis in our institution. A four chamber view of the fetal heart is done as a part of regular sonographic examination of the fetus. Most cases of congenital heart disease are of structural rather than functional origin. *Aims & objectives:* To determine cardiac length (major longitudinal diameter) of the fetal heart during the third trimester of pregnancy. To evaluate the relationship between fetal heart dimensions obtained from sonography (cardiac length) and Gestational age (weeks) Biparietal diameter (mm) Femur length (mm) & abdominal circumference. *Materials & Methods:* The fetal heart was studied with transabdominal sonography in 132 single normal pregnancies in third trimester Measurement of cardiac length (longitudinal diameter) of the heart was taken. Gestational age was assessed by fetal parameters that are biparietal diameter, femur length and abdominal circumference as per the norms in one of the Mumbai's medical teaching institute and tertiary care centre. *Results:* The linear increase of the fetal heart shows a strong and significant correlation with the increase of biparietal diameter, femur length and abdominal circumference. Relationships between the cardiac data and fetal age, biparietal diameter, femur length and abdominal circumference were explored by allometry and linear regression analysis in order to estimate cardiac growth rates during third trimester. *Conclusion:* This study verified that the heart grows very rapidly during the third trimester (positive allometry). This suggests that noninvasive analysis of cardiac data can be useful for the assessment of gestational age or for prenatal detection of congenital heart disease [1].

Keywords: USG; BPD; FL; AC; & CL.

Introduction

It has been proposed that a satisfactory four chamber view of the heart may be obtained in 95% of pregnancies after 18 weeks [2]. The importance of a normal four- chamber view has been emphasized by Copel et al., who showed that if this view on transabdominal ultrasonographic study was normal,> 90% of congenital heart anomalies could be ruled out [3].

Cardiac defect, the most common form of congenital defects, are found in 3 to 8 of every 1000 pregnancies. They account for 45 % of infant deaths from congenital defects, which is a far greater proportion than any other organ system [5].

The more severe the growth disturbance, the greater the disparity between the actual gestational age prediction by standard biometry, the size of the fetal heart is less affected by abnormalities in fetal growth than are other organ system [4].

Most cases of congenital heart disease are of structural rather than functional origin. Therefore distortion of the normal cardiac anatomy is an important finding on antenatal ultraasonographic evaluation [6].

If the diagnosis of congenital heart disease occurs prior to 23 weeks of gestation the patient has the option of termination of pregnancy. If a malformation is diagnosed in the third trimester, the fetus should be delivered at a facility equipped to care of the infant with congenital heart disease [7].

Therefore, it is important to recognize a possible abnormality on a four chamber view of the of the heart

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because it allows

1. Time for a second look at fetal echocardiography for a more precise diagnosis.
2. Prenatal counseling for parents.
3. Time for planned delivery.
4. Time for relocation of family to centers equipped to handle such cases.
5. Search time when heart transplantation is considered.
6. And eliminates delay in definite diagnosis and treatment[2]

Sonographic scan is noninvasive and safe modality for imaging fetal heart.

Since this procedure is done on routine basis in our institution I preferred to work upon it as my dissertation.

Aims and Objectives

Based on these facts and the ease as well as the availability of the resources guided the following aims and objectives for the study of dimension of fetal heart.

1. To determine cardiac length (major longitudinal diameter) of the fetal heart during the third trimester of pregnancy.
2. To verify that heart grows rapidly during the third trimester (positive allometry) and to note any congenital anomalies associated with them if present.
3. To evaluate the relationship between fetal heart dimensions obtained from sonography (cardiac length) and
   a. Gestational age (weeks)
   b. Biparietal diameter (mm)
   c. Femur length (mm)
   d. Abdominal circumference (mm)

Materials and Methods

A prospective study was conducted in one of the Mumbai's medical teaching institute and tertiary care centre. This study was done in collaboration with the Department of Radiology. Ethics committee permission was obtained prior to the commencement of the study.

One hundred and thirty two normal pregnant women in third trimester coming for routine antenatal ultrasonography were included in the study. Before doing sonography patients were informed about study and consent was taken after full satisfaction. The name and address of the pregnant women were documented as an identity mark. The obstetrics history and LMP (last menstrual period) was recorded. Gestational age was documented by LMP.

In the present study the cardiac 4-chamber view was studied by the traditional transabdominal scan because the heart is large enough in third trimester to be well examined with this technique.

The fetal heart was studied by transabdominal sonography to analyze the increase of cardiac length (major longitudinal diameter of the heart) during the third trimester. Relationships between the cardiac data and fetal age, femur length, biparietal diameter (BPD) and abdominal circumference (AC) were explored by allometry and linear regression analysis.

The third trimester was considered from 24 weeks to term. One hundred and thirty two single pregnancies without special medical problems were studied with transabdominal sonography covering four age groups viz.

a. 24-27.9 weeks (22 fetuses),
b. 28-31.9 weeks (50 fetuses),
c. 32- 35.9 weeks (50fetuses),
d. 36-40 weeks (10 fetuses).

The assessment of the gestational age considered by femur length, biparietal diameter and abdominal circumference as per the norms in one of the Mumbai's medical teaching institute and tertiary care center.

The femur is measured from the proximal to the distal end of the shaft the femoral head and distal epiphysis are not included in the measurement [19] (Fig. 1). As stated the rules for measurement of the femur are as follows, First align the transducer to the femur and freeze the plane that shows both the cartilaginous femoral head and distal condyle. Then place the measurement cursors at the junction of the cartilage and bone, being careful to avoid the distal femoral point [8].

The rules for measuring the BPD are as shown in Fig. 2. The rules of measurement of the fetal AC are as shown in Fig. 3. The length of the heart could be measured reproducibly in the 4-chamber view of the heart (Fig. 4).

Four Chamber View of the Normal Fetal Heart-

Normal orientation in the fetal chest-

Opposite of the spine → sternum.

Just posterior to sternum → right ventricle.

Just in front and left to the spine → descending aorta.

Just anterior to the descending aorta → left atrium [8].

The 4-chamber view with a detailed image of the heart was usually obtained with transabdominal scan in the third trimester an average time of 15 minutes was normally sufficient to perform the sonographic observation and to obtain a suitable image of the heart.

The length of the heart were recorded considering the major longitudinal length of the 4-chamber view of the heart (Fig. 5, 6). Cardiac length was measured between the sulcus terminalis immediate right of superior vena cava and the apex of heart. All the dimensions were taken in mm. After entire scanning the required images were saved on the machine. These were later transferred on a CD and a soft copy was made.

The data collection was completed within the stipulated time given by the Ethics committee. After having done with the final formalities, the data was compiled together. The total data of 132 pregnant women collected, was numbered serially as per the sequence of the collection and thus master chart was made. The data of pregnant women's were later grouped and statistically evaluated.

Relationships between the growth of the cardiac measurement and fetal parameters were explored by allometry and linear regression analysis in order to estimate cardiac growth rates during the third trimester.

The measurements of the heart (the dependent variable Y) were correlated with the fetal parameters (the independent variable X) after logarithmic transformation using the following model:

$$\text{Ln}Y = \text{Ln}\, a + (b)\, \text{Ln}\, X$$

R- Squared and F statistics were used to determine the significance of each regression and a t-test was used to determine the significance departure from a predicted slope at the alpha = 0.05 level. The validity of a linear model was examined with residual analysis. The use of log transformed data was important to overcome the situation of standardized residuals heterocedasticity due to increasing variability in Y with increasing values of X [9].

Because of the problem of biased estimates of slopes of Y on X when both variables are subject to measurement error, the slope of the principle axis of the standardized variables viz. reduced major axis (RMA, regression model II), was computed [9]. Each regression slope was checked for departure from isometry. A slope of 1 indicates isometry in the conditions of the present study [10].

Observations and Results

Correlation between Cardiac Length and Gestational age Correlations

		Ageusg	Cardialen
Ageusg	Pearson Correlation	1	.882(**)
	Sig. (2-tailed)		.000
	N	132	128
Cardialen	Pearson Correlation	.882(**)	1
	Sig. (2-tailed)	.000	
	N	128	128

** Correlation is significant at the 0.01 level (2-tailed).

Graph 1:

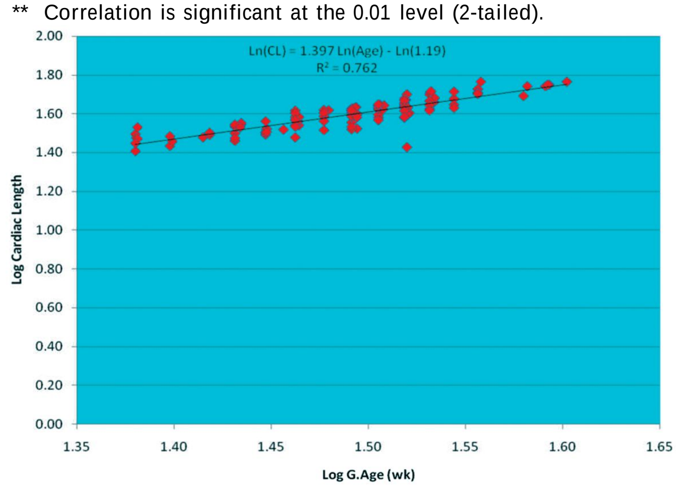


Table 1: Correlation between cardiac length and gestational age after regression analysis

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.874(a)	.764	.762	.08718

a Predictors: (Constant), logage

ANOVA(b)

Model		Sum of Squares	DF	Mean Square	F	Sig.
1	Regression	3.104	1	3.104	408.421	.000(a)
	Residual	.958	126	.008		
	Total	4.061	127			

a Predictors: (Constant), logage
b Dependent Variable: logcarlen

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Upper bound	Lower boundr
1	(Constant)	-1.119	.237		-4.716	.000	-1.588	-.649
	logage	1.397	.069	.874	20.209	.000	1.260	1.534

a Dependent Variable: logcarlen

Ln Y = (b) Ln X + a

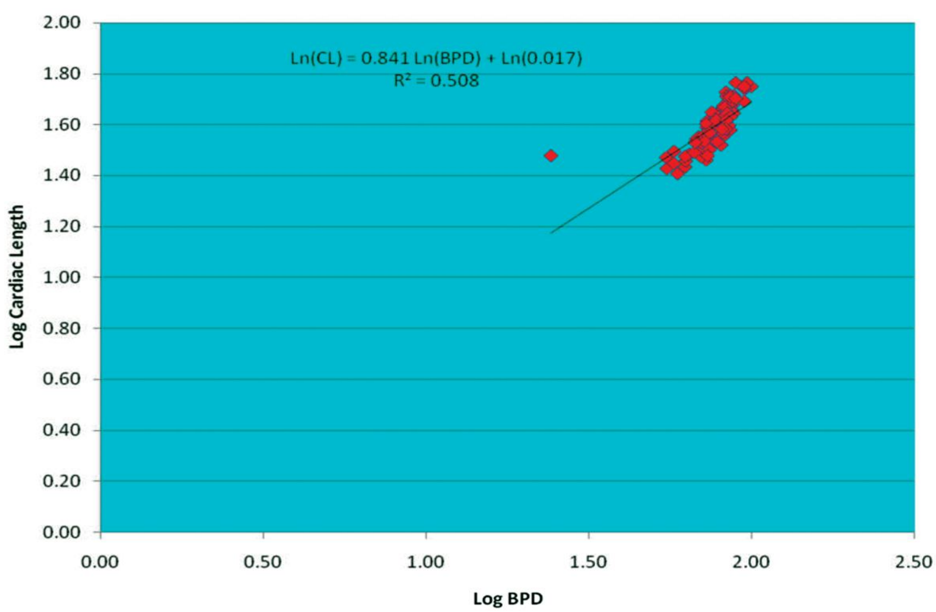
Ln (CL) = 0.874 Ln (GA) -1.119

Correlations between cardiac length and gestational age were assessed by using Pearson's correlation coefficient. It was found to be positively correlated, r = 0.882, which was statistically significant p < (0.001). To predict cardiac length from gestational age we used linear regression analysis. Coefficient of determination was found to be 0.764 that is 76.4% variation in cardiac length can be accounted by knowing gestational age. Regression model was found to be statistically significant with ANOVA test (p <0.001). Coefficient of regression (slope of the regression equation) was also statistically significant (p< 0.001). From Table. 1 equation for predicting cardiac length will be

Ln (CL) = (b) Ln (GA) + a

It can be concluded that cardiac length growth rate is allometrically positive in relation to fetal age.

Correalation between Cardiac Length and Biparietal Diameter



Graph 2:

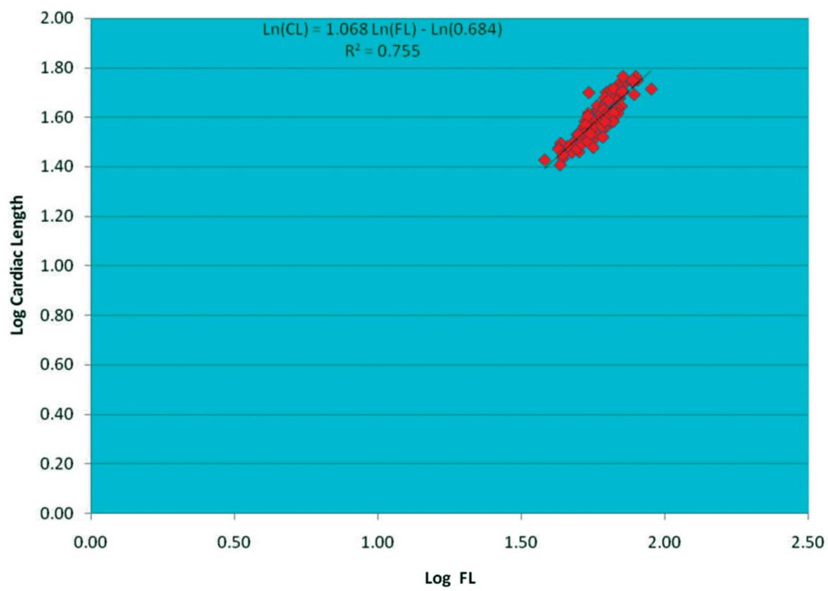
Table 2: Correlations

		Ageusg	Femurlen	Bpd	Ac	Cardialen
Ageusg	Pearson Correlation	1	.897(**)	.852(**)	.796(**)	.882(**)
	Sig. (2-tailed)		.000	.000	.000	.000
	N	132	132	131	130	128
Femurlen	Pearson Correlation	.897(**)	1	.838(**)	.793(**)	.860(**)
	Sig. (2-tailed)	.000		.000	.000	.000
	N	132	132	131	130	128
Bpd	Pearson Correlation	.852(**)	.838(**)	1	.743(**)	.801(**)
	Sig. (2-tailed)	.000	.000		.000	.000
	N	131	131	131	129	127
Ac	Pearson Correlation	.796(**)	.793(**)	.743(**)	1	.771(**)
	Sig. (2-tailed)	.000	.000	.000		.000
	N	130	130	129	130	127
Cardialen	Pearson Correlation	.882(**)	.860(**)	.801(**)	.771(**)	1
	Sig. (2-tailed)	.000	.000	.000	.000	
	N	128	128	127	127	128

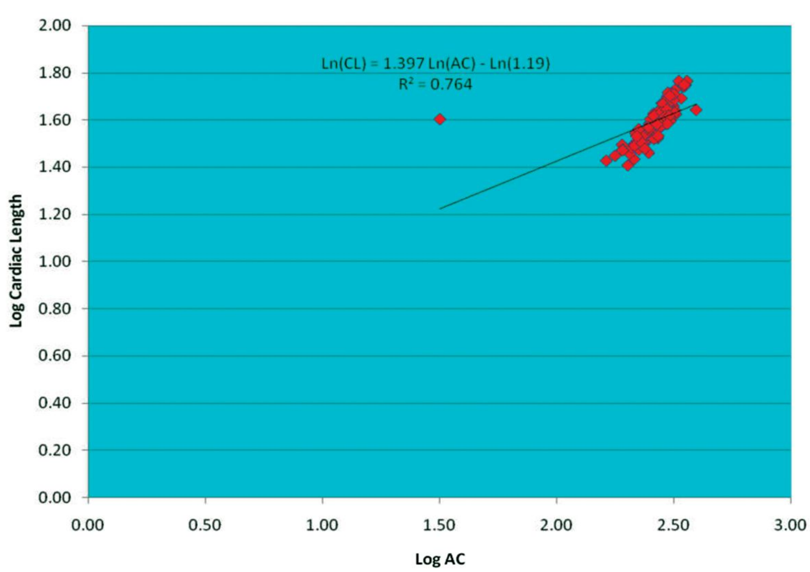
** Correlation is significant at the 0.01 level (2-tailed)

Correlation between Cardiac Length and Femur Length

Graph 3:



Correlation between Cardiac Length and Abdominal Circumference



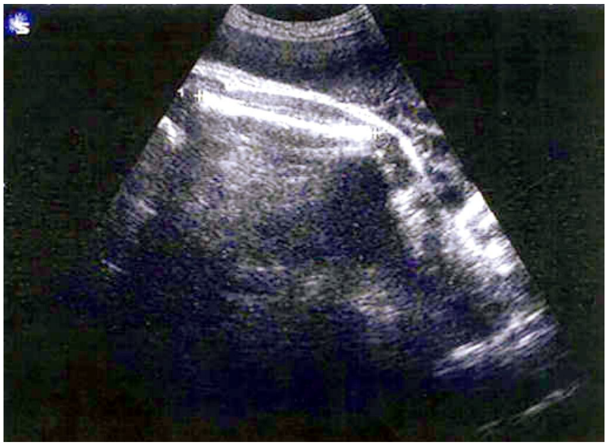


Fig. 1: The femur is measured from the origin to the distal end of the shaft the femoral head and distal epiphysis are not included in the measurement (note the measurement is 71.7mm real time scan)

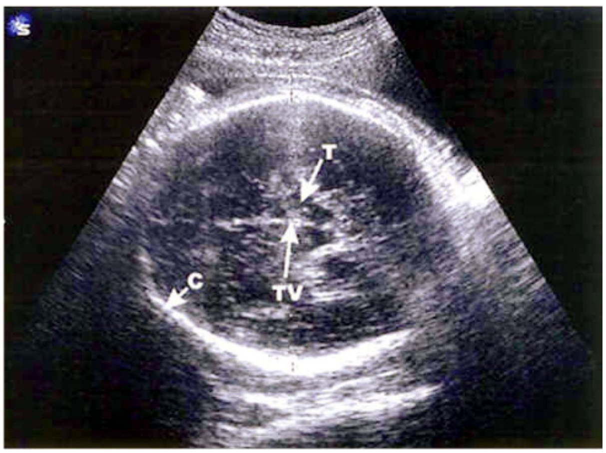


Fig. 2: An accurate biparietal diameter can be obtained through any plane of section that intersects the third ventricle (TV) and the thalami (T). The margins of the calvaria must be (C) symmetric. The first criterion ensures that the plane of section is taken at the proper craniocaudal plane. The second criterion ensures that the transducer is oriented perpendicular to the central axis of the head (note the measurement is 86.1mm, real time scan)

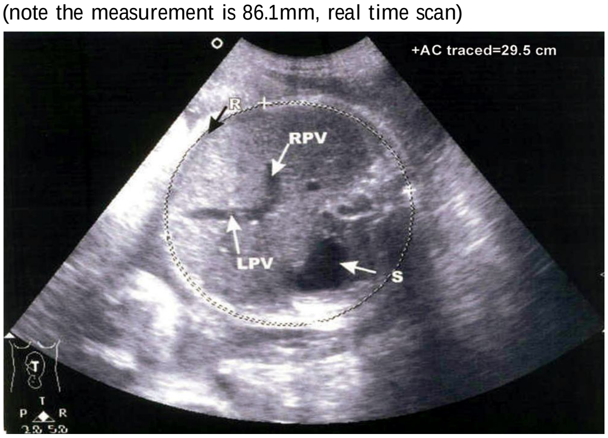


Fig. 3: The rules of measurement of the fetal AC are, the correct cephalocaudal plane is the position where the right and left portal veins are continuous with one another. Second, the appearance of the lower ribs is symmetric. Finally, the shortest length of the umbilical segment of the portal vein is depicted. The body of the fetal stomach is nearly always visible in a well performed AC measurement (note the measurement is 295 mm, real time scan)

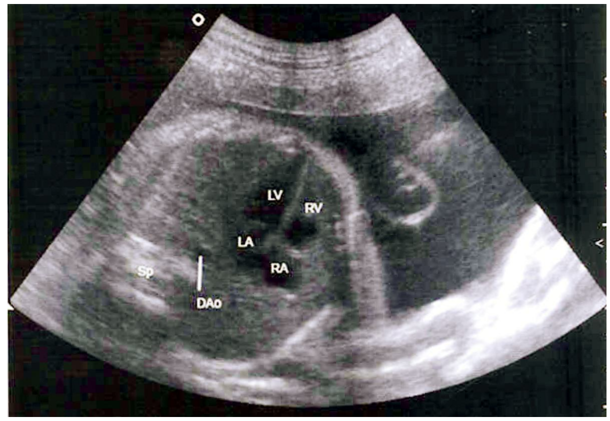


Fig. 4: Normal four chamber view of the fetal heart. The orientation shows the descending aorta (DAo) close to the spine (Sp), the left atrium (LA) anterior to the descending aorta, and the right ventricle (RV) behind the anterior chest wall. The heart covers about one-third of the thoracic cross-sectional area; the apex points to the left anterior chest wall (real time scan)

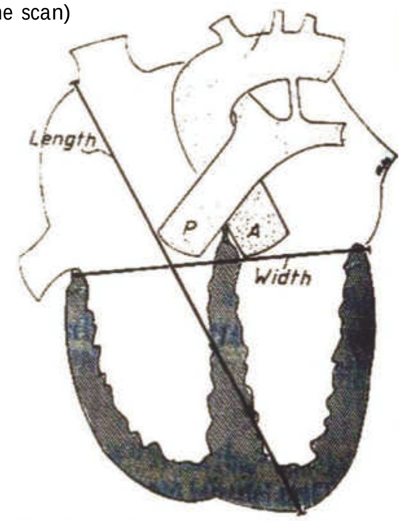


Fig. 5: Schematic drawing of a frontal section of the heart showing where the measurements were taken. Cardiac length between the sulcus terminalis immediate right of the superior vena cava and apex of the heart.

Fig. 6: transabdominal sonographic 4-chamber view of the fetal heart in 24 weeks pregnancy where the measurements were taken. Cardiac length between the sulcus terminalis immediate right of the superior vena cava and apex of the heart.

Fig. 7 A: Transabdominal sonographic view of biparietal diameter in a 26 weeks fetus (real time scan)

Fig. 7 B: Transabdominal sonographic view of femur length in a 26 weeks fetus (real time scan)

Fig. 7 C: Transabdominal sonographic view of abdominal circumference in 26 weeks fetus (real time scan)

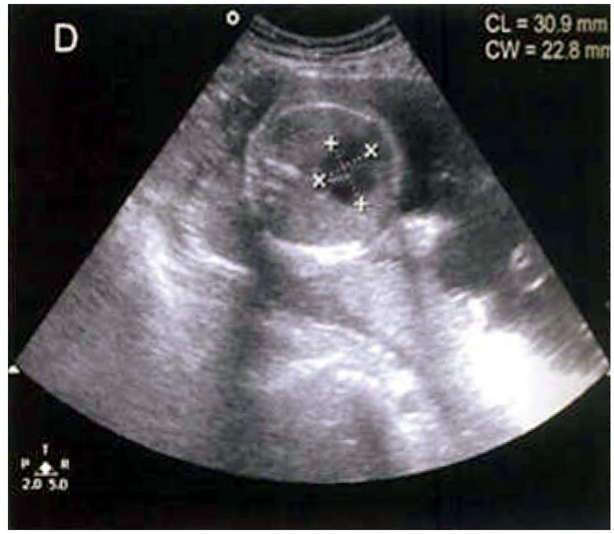


Fig. 7 D: Transabdominal sonographic 4-chamber view of the fetal heart in a 26 weeks fetus (note the cardiac length is 30.9mm real time scan)

Fig. 8 A: Transabdominal sonographic view of biparietal diameter in 36 weeks fetus (real time scan)

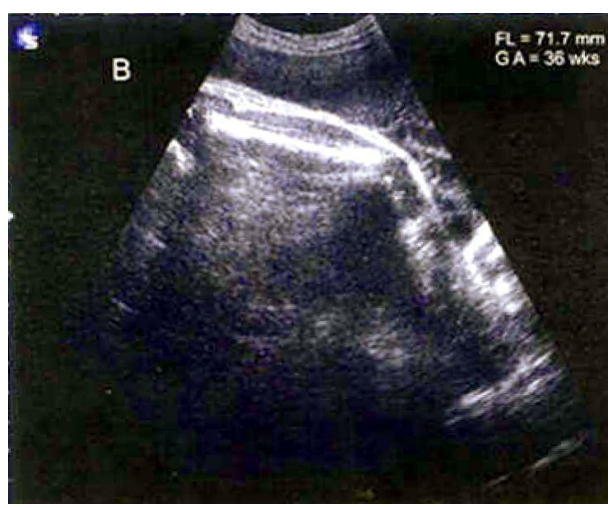


Fig. 8 B: Transabdominal sonographic view of femur length in a 36 weeks fetus (real time scan)

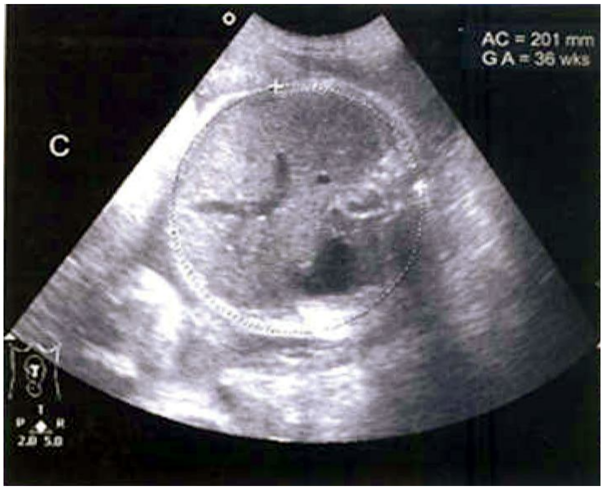


Fig. 8 C: Transabdominal sonographic view of abdominal circumference in a 36 weeks fetus (real time scan)

Fig. 8 D: Transabdominal sonographic 4- chamber view of the fetal heart in a 36 weeks fetus (note the cardiac length is 41.9mm real time scan)

Discussion

It is obviously important to understand cross-sectional cardiac images, if possible, in the physiological state, both for the clinician and the anatomist. The clinician can use this knowledge to aid in diagnosis, and the anatomist can use it better to understand and describe subtle anatomical structures that may be difficult to visualize on gross dissection[11].

Allometry is the change in shape with size. The growth of the human heart was proved to be allometrically positive during fetal life. This suggests a high cardiac growth rate in this third trimester period, with major changes in the shape of the heart.

For estimating fetal age and size[12] in general there are three statistical tools used for predicting fetal age or size by sonography – a table or graph, regression formula and a ratio that is used to compare relative sizes of one parameter with another parameter

The last menstrual period (LMP) is the most common method for estimating expected date of delivery for a fetus. The problem with dating of pregnancy is that not all the women have same menstrual length. Stress and anxiety lengthen the menstrual cycle and the time of fertilization and implantation after the LMP varies somewhat. For these reasons, predicting the date of pregnancy from LMP varies from actual sonographic measurement. Naegele's formula is commonly used to estimate the expected date of delivery (EDD). The EDD is by adding seven days to LMP and counting back 3 months.

Presently measuring the multiple fetal ultrasonographic parameters is the most effective way for evaluation of fetal growth and detection of abnormal fetal growth.

Prenatal diagnosis allows time for a thorough counseling and allows the family to make an informed decision regarding continuation or termination of pregnancy, instigation of medical therapies, preparation for postnatal cardiac surgery, and more recently, the possibility of invasive intrauterine interventions such as valvuloplasties [13].

Confirmation of the diagnosis led to a multidisciplinary approach, with involvement of a paediatric cardiologist, a geneticist, and the obstetrician, so that the most accurate information could be given to the parents to help them in the decision-making process [6].

Perioperative morbidity and mortality are lower for prenatally diagnosed cardiac lesions, as delivery can be arranged in a center with adequate neonatal resuscitation and surgical facilities [13].

In the present study four chamber view of the heart was selected. It has been suggested that incorporation of the four chamber view of the fetal heart into routine obstetric scanning may improve the diagnostic rate of congenital heart disease. The highest incidence of (50)% of congenital heart disease occurs in cases referred because of a suspected congenital heart disease on a routine ultrasonographic scan [6].

Wernovsky et al., mention that a continuation of the application of the arterial switch operation to patients with transposition of the great arteries with or without VSD, as early in life as is possible, is indicated [14].

Brawn and Mee et al., advocate anatomic repair of TGA-VSD and DORV-VSD before 3 months of age to correct symptoms of congestive failure to thrive and to prevent the development of pulmonary vascular disease [15].

It is well known that early neonatal diagnosis and treatment of congenital heart disease can improve outcome, especially when complex malformations are present [7].

An increasing number of obstetricians are performing fetal screening scans that include a four-chamber view of the heart. This has led to a large increase in the number of referrals for fetal echocardiography [16].

Postnatal survival in newborns with critical congenital heart disease largely depends on the timely initiation of specific treatment. Prenatal diagnosis followed by delivery at a tertiary care institution with an expertise in management of newborns with heart disease allows timely institution of specific treatment [17].

In the present work the cardiac 4-chamber view was studied by the traditional transabdominal scan because the heart is large enough in third trimester to be well examined with this technique. The transabdominal approach is a simpler and less expensive method to evaluate the pregnancy and the developing fetus than is transvaginal sonography.

The transversal heart diameter, ventricular dimensions, interventricular septal thickness, heart area, cardiothoracic diameter ratio, aortic diameter and the pulmonary trunk diameter showed a highly significant linear correlation to the gestational age and the biparietal diameter [18].

The introduction of high quality equipment [19], as well as better understanding of fetal anatomy and physiology, has resulted in improved accuracy of fetal echocardiography in recent years. In fact, accuracy of complete anatomic assessment is now possible after 18 to 20 weeks gestation [20]. False positive prenatal diagnosis of anatomic heart disease is rare [21].

In the present study quantitative analysis of fetal heart was carried out in the randomly selected 132 pregnant women who came for routine antenatal sonography. Growth of the cardiac measurements and fetal parameters were explored by allometry and linear regression analysis. Gestational age is assessed by BPD, FL, and AC as per norms in one of the Mumbai's medical teaching institute and tertiary care centre. Then the cardiac length were correlated with gestational age, BPD, FL, and AC.

In above study growth of the cardiac measurements and fetal parameters were explored by allometry and linear regression analysis [1].

In present study relationship between gestational age and growth of cardiac length was explored by allometry and linear regression analysis (Table 1). This method uses an independent variable(X) to predict the value of a dependent variable (Y).

Here independent variable GA, BPD, FL & AC was used to predict dependent variable CL. Correlation between cardiac length and gestational age, biparietal diameter, femur length & abdominal circumferance was assessed by using Pearson's correlation coefficient it was found to be positively correlated (Table 1,2 & Graph 1,2,3 & 4). Regression model was found to be statistically significant with ANOVA test ($p < 0.001$). Coefficient of regression (slope of the regression equation) was also statistically significant ($p < 0.001$). Thus it was concluded that cardiac length growth rate was allometrically positive in relation to fetal age, BPD, FL & AC.

Similar previous study, Sonographic quantitative analysis of the heart in the third trimester of gestation by Mandarim-de-Lacerda CA et al., in which fetal parameters were BPD , FL. In the study by Mandarim-de-Lacerda CA et al., linear regression of the increase of the cardiac length relative to gestational age was done in which slope (b) was found to be 1.458, intercept was -1.701, 95% confidence interval for b was 1.207-1.709 and coefficient of regression was found to be 0.851.The present study result matches with that of the above mentioned study.

There was significant correlation seen in the dependent parameters i.e. cardiac length and independent parameters i.e. gestational age, biparietal diameter, femur length and abdominal circumference (Table 2).

Allometry is the change in shape with size. The growth of the human heart was proved to be allometrically positive during fetal life. This suggests a high cardiac growth rate in this third trimester period, with major changes in the shape of the heart[1].

Summary and Conclusions

Advanced technology as well as increased capability of sonographers and sonologists have expanded the use of ultrasonography as a diagnostic obstetric tool for the evaluation of fetal anatomy. The uses of ultrasonography are varied; in obstetrics, its use has become crucial and vital especially in accurate determination of gestational age in women with unknown last menstrual period.

The fetal heart was studied with transabdominal sonography in 132 single normal pregnancies in third trimester. The third trimester was considered from

24 weeks to term covering four age groups viz. 24-27.9 weeks (22 fetuses), 28-31.9 weeks(50 fetuses), 32-35.9 (50 fetuses), 36-40 weeks (10 fetuses).

Measurement of cardiac length (major longitudinal diameter) of the heart was taken. Gestational age was assessed by fetal parameters that are biparietal diameter, femur length and abdominal circumference as per the norms in one of the Mumbai's medical teaching institute and tertiary care centre.

Relationships between the cardiac data and fetal age, biparietal diameter, femur length and abdominal circumference were explored by allometry and linear regression analysis in order to estimate cardiac growth rates during third trimester. The length of the heart could be measured reproducibly in the 4-chamber view of the heart.

The cardiac length was 30.9mm in fetuses up to 26 weeks. These measurents were seen to gradually increase as the fetuses advanced such that at 36 weeks of gestation it was seen to be 41.9mm (Fig. 7 & 8).

There was significant correlation seen in the dependent parameter i.e.cardiac length and independent parameters i.e. gestational age, biparietal diameter, femur length and abdominal circumference.

This study verified that the heart grows very rapidly during the third trimester (positive allometry). The linear increase of the fetal heart shows a strong and significant correlation with the increase of biparietal diameter, femur length and abdominal circumference.

This suggests that noninvasive analysis of cardiac data can be useful for the assessment of gestational age or for prenatal detection of congenital heart disease.

Aknowledgment

I would like to thank Dr. Pritha Bhuiyan, Professor & Head, Department of Anatomy Seth G S Medical College & KEM Hospital Mumbai.

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